



US009275703B2

(12) **United States Patent**
Lee et al.

(10) **Patent No.:** **US 9,275,703 B2**
(45) **Date of Patent:** **Mar. 1, 2016**

(54) **SEMICONDUCTOR INTEGRATED CIRCUIT WITH STACK PACKAGE STRUCTURE**

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,466,577 B2 * 12/2008 Sekiguchi et al. 365/51
2012/0286414 A1 * 11/2012 Meyer-Berg 257/698
2013/0021866 A1 * 1/2013 Lee 365/230.01

FOREIGN PATENT DOCUMENTS

KR	1020000038255	7/2000
KR	1020010098910	11/2001
KR	1020020004860	1/2002
KR	1020030069872	8/2003
KR	1020050069925	7/2005
KR	1020110068762	6/2011
KR	1020120096297	8/2012

* cited by examiner

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 172 days.

(21) Appl. No.: **13/719,096**

(22) Filed: **Dec. 18, 2012**

(65) **Prior Publication Data**

US 2014/0003168 A1 Jan. 2, 2014

(30) **Foreign Application Priority Data**

Jun. 29, 2012 (KR) 10-2012-0071270

(51) **Int. Cl.**

G11C 7/00 (2006.01)
G11C 7/22 (2006.01)
G11C 8/18 (2006.01)
G11C 7/10 (2006.01)

(52) **U.S. Cl.**

CPC .. **G11C 7/22** (2013.01); **G11C 7/10** (2013.01);
G11C 7/1012 (2013.01); **G11C 7/1039**
(2013.01); **G11C 7/1042** (2013.01); **G11C 8/18**
(2013.01); **G11C 2207/107** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(57) **ABSTRACT**

A semiconductor integrated circuit including first semiconductor chip and second semiconductor chip that are vertically stacked, wherein the first semiconductor chip includes a first column data driving circuit configured to transmit internal data to the second semiconductor chip in a DDR (double data rate) scheme based on an internal strobe signal, and a first column strobe signal driving circuit configured to generate first column strobe signals that are source-synchronized with first column data transmitted to the second semiconductor chip by the first column data driving circuit, based on the internal strobe signal, and transmit the first column strobe signals to the second semiconductor chip.

14 Claims, 8 Drawing Sheets

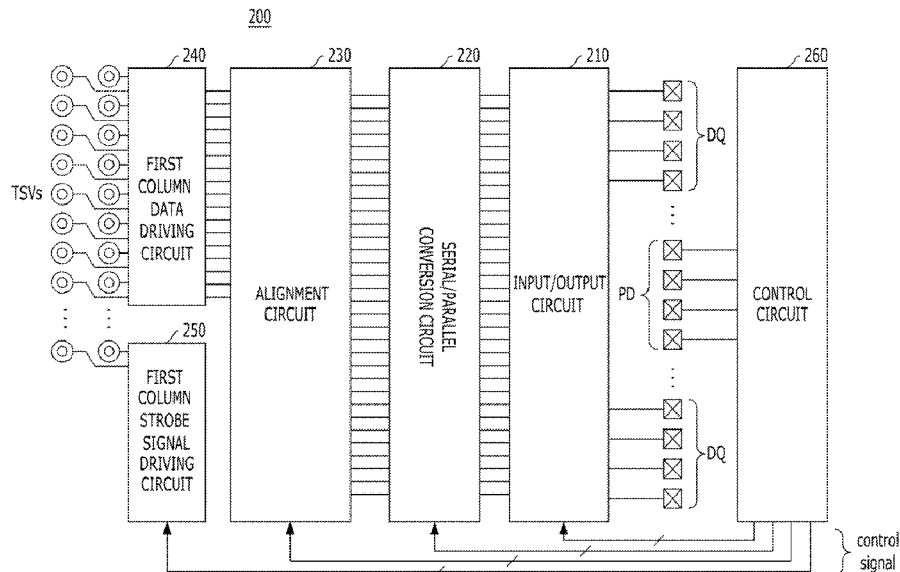


FIG. 1
(PRIOR ART)

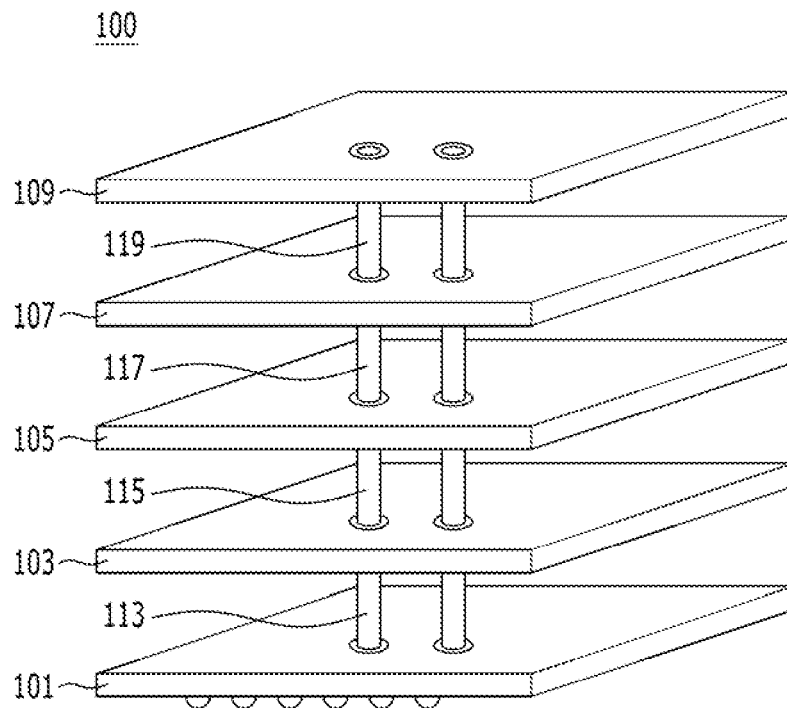


FIG. 2

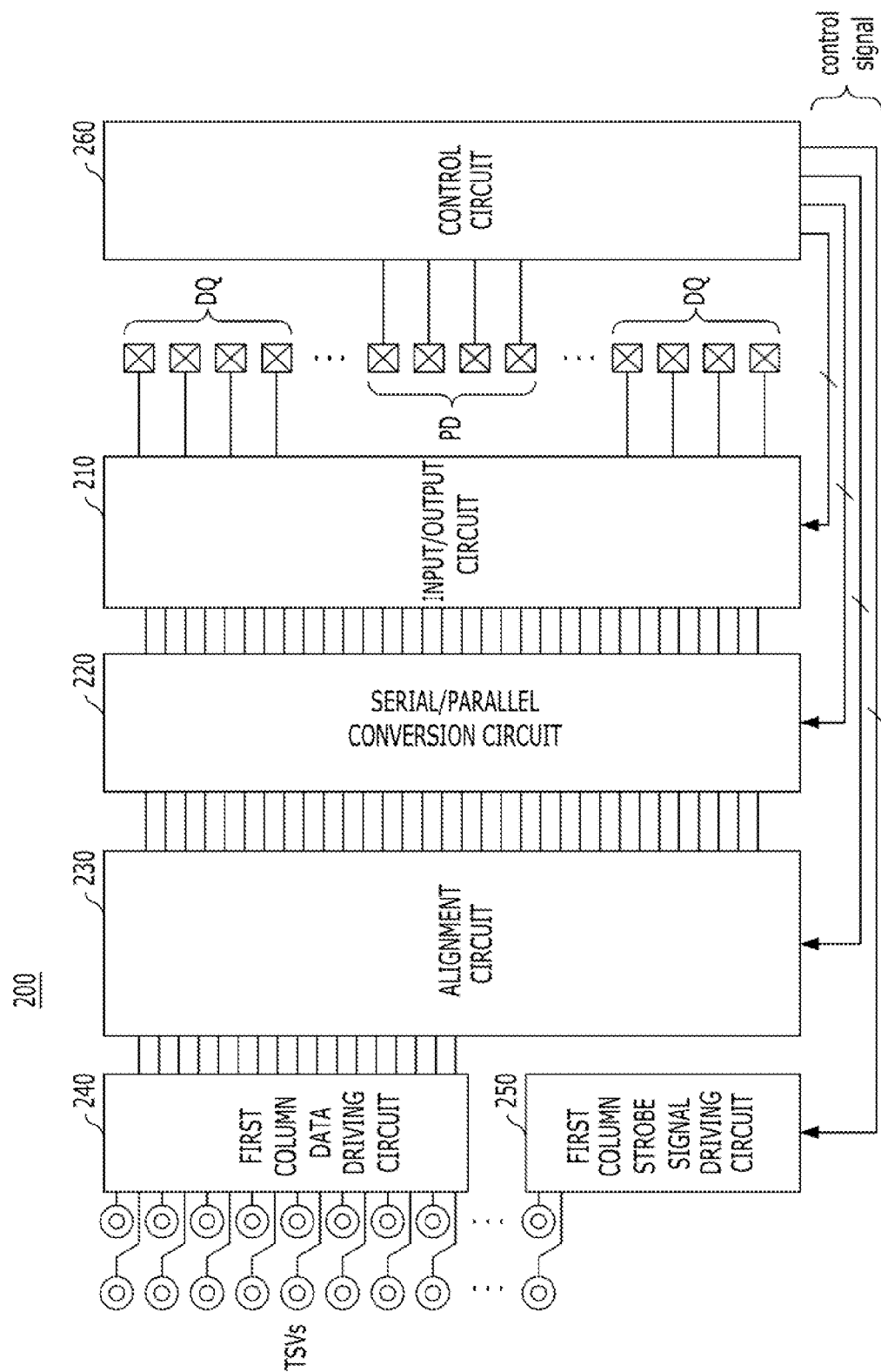


FIG. 3

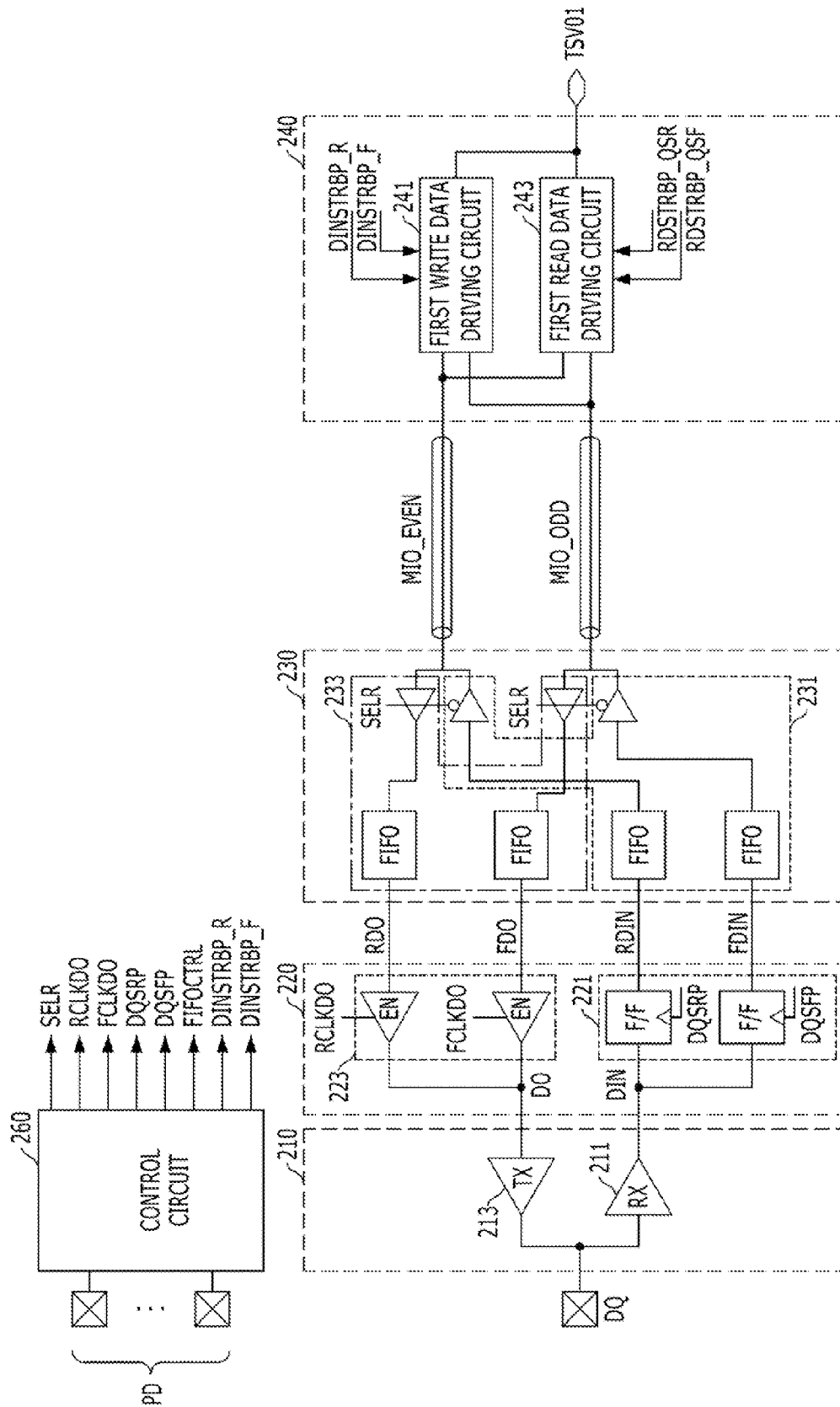


FIG. 4

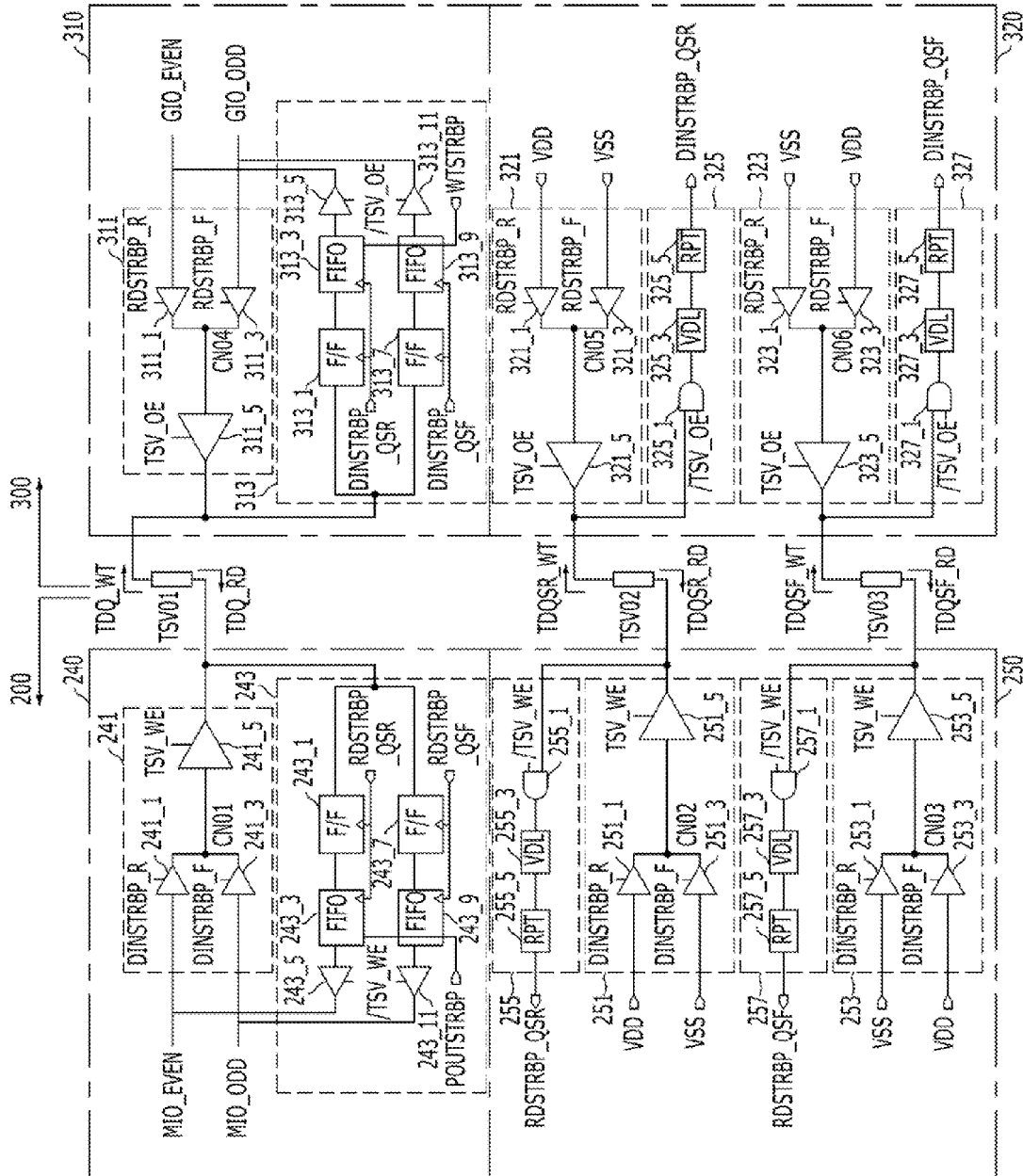


FIG. 5

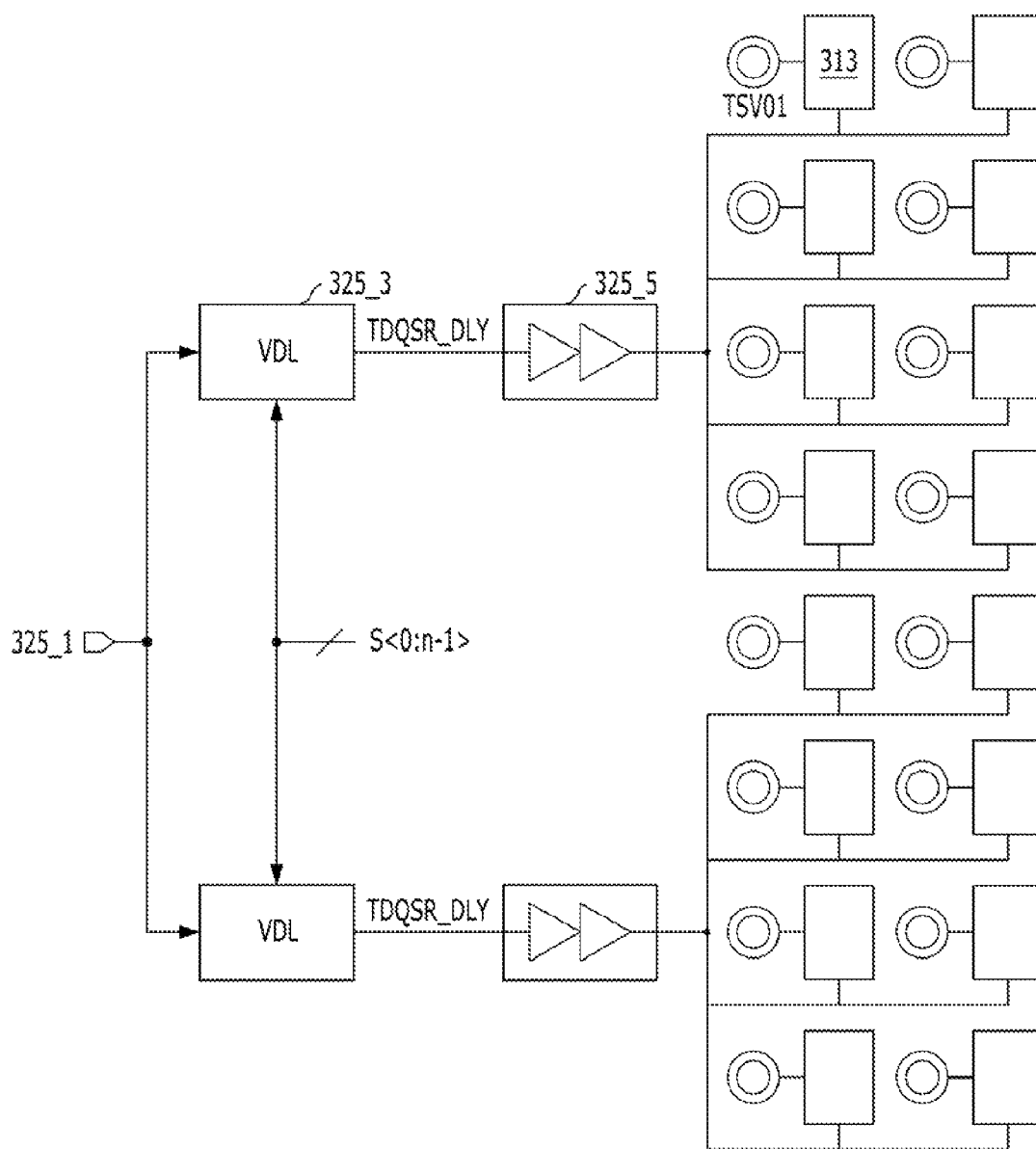


FIG. 6

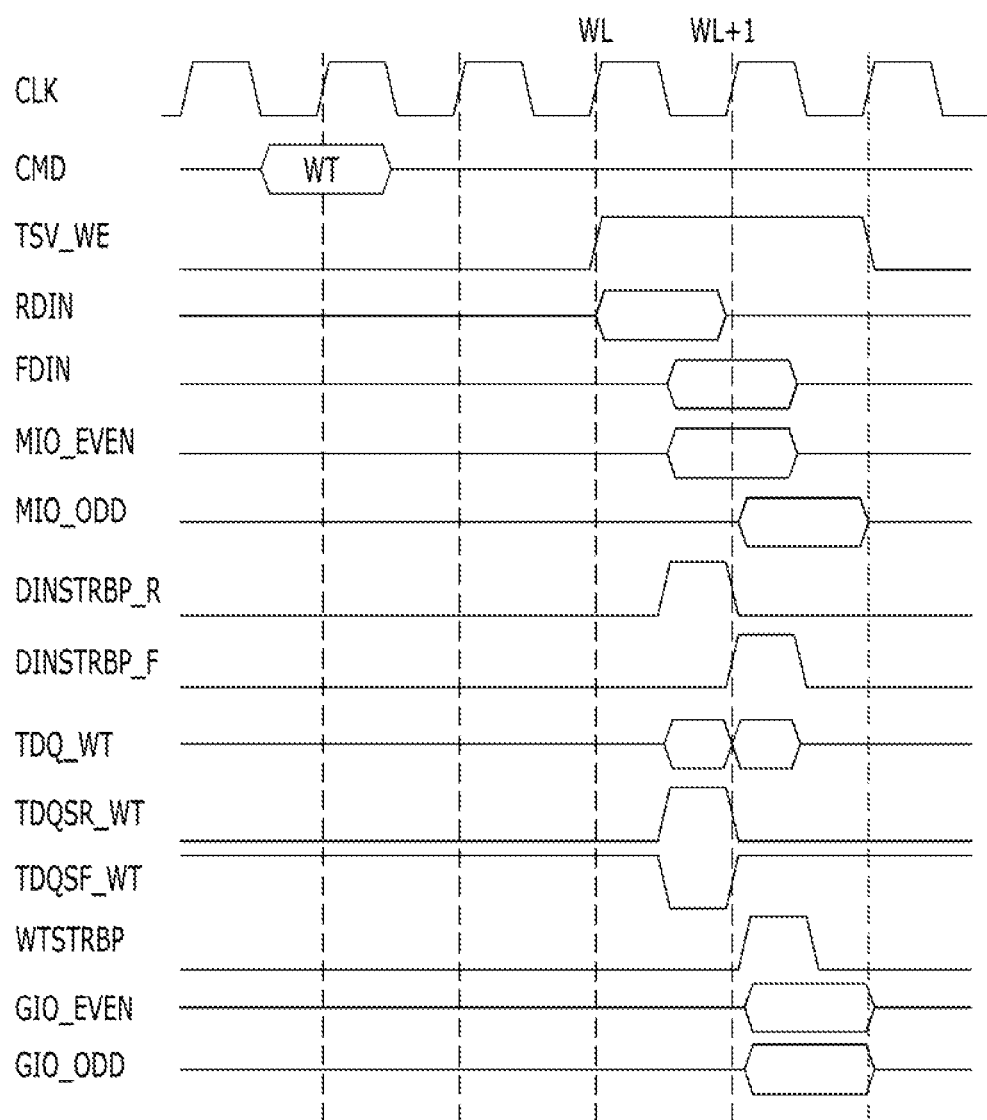


FIG. 7

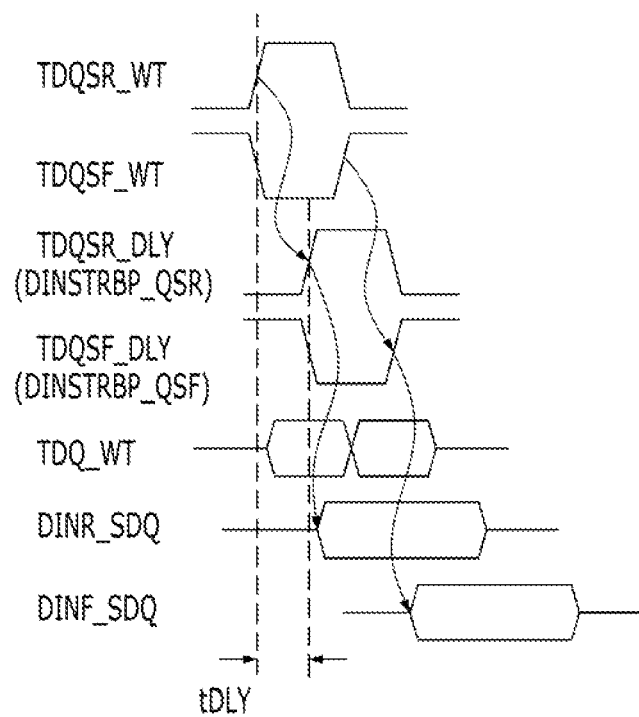
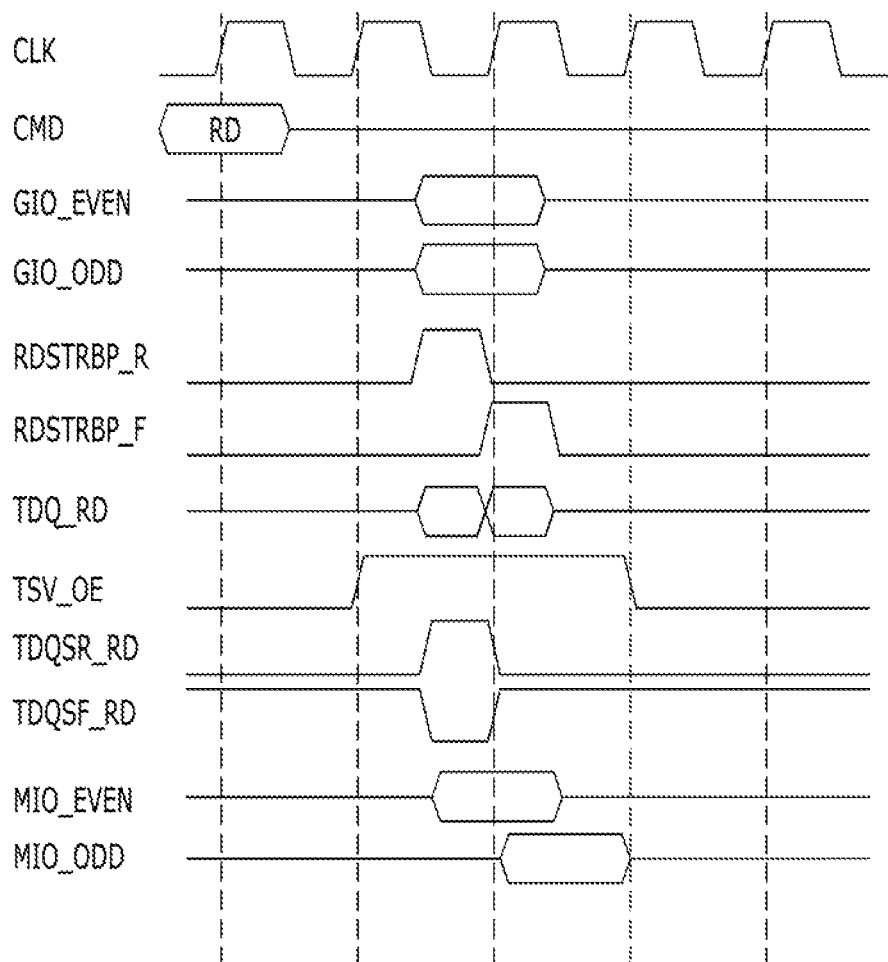


FIG. 8



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SEMICONDUCTOR INTEGRATED CIRCUIT WITH STACK PACKAGE STRUCTURE

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims priority of Korean Patent Application No. 10-2012-0071270, filed on Jun. 29, 2012, which is incorporated herein by reference in its entirety.

BACKGROUND

1. Field

Exemplary embodiments of the present invention relate to a semiconductor design technology, and more particularly, to a semiconductor integrated circuit with a stack package structure.

2. Description of the Related Art

In general, packaging technologies for semiconductor integrated circuits have continuously been developed to satisfy the demand toward reducing size and mounting reliability. Recently, as reduction in size and high performance are demanded in electric and electronic products, various techniques for stack packages have been developed.

The term “stack” that is referred to in the semiconductor industry means to vertically pile at least two semiconductor chips or semiconductor packages. For example, in the case of a semiconductor memory device, by using a stack package, a product with memory capacity at least two times greater than that obtainable without a stack package may be realized. Since the stack package provides advantages in terms of not only memory capacity but also mounting density and mounting area utilization efficiency, research and development for the stack package have been accelerated.

Generally, a stack package may be fabricated through a method in which individual semiconductor chips are stacked and then the stacked semiconductor chips are packaged at once or a method in which individually packaged semiconductor chips are stacked. The individual semiconductor chips of the stack package are electrically connected through metal wires or through-chip vias. Specifically, a stack package using through-chip vias has a structure in which through-chip vias are formed in the individual semiconductor chip such that physical and electrical connections between the semiconductor chips are formed by the through-chip vias.

FIG. 1 is a perspective view for illustrating a semiconductor integrated circuit in which electrical connections are formed through through-chip vias.

Referring to FIG. 1, a semiconductor integrated circuit 100 includes a first semiconductor chip 101 which is electrically connected with an external controller (not shown), second to fifth semiconductor chips 103, 105, 107 and 109 that are vertically stacked on the first semiconductor chip 101, and a plurality of first to fourth through-chip vias 113, 115, 117 and 119 that vertically pass through the second to fifth semiconductor chips 103, 105, 107 and 109.

The first semiconductor chip 101 is configured to control the second to fifth semiconductor chips 103, 105, 107 and 109 through the first to fourth through-chip vias 113, 115, 117 and 119 based on various signals and power provided from the external controller, and is generally referred to as a master chip.

The second to fifth semiconductor chips 103, 105, 107 and 109 are semiconductor chips for performing given operations under the control of the first semiconductor chip 101, and are generally referred to as slave chips.

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The first to fourth through-chip vias 113, 115, 117 and 119 are formed of a metal with high conductivity, and are generally referred to as through-silicon vias (TSVs).

According to the semiconductor integrated circuit 100, as the various signals and power are interfaced through the first to fourth through-chip vias 113, 115, 117 and 119, advantages are provided in that signal delay and current consumption may be decreased and operation performance may be improved due to improved I/O bandwidth.

However, the semiconductor integrated circuit 100 configured as mentioned above has the following concerns.

While it is illustrated in FIG. 1 that the respective semiconductor chips 103, 105, 107 and 109 have two through-chip vias 113, 115, 117 and 119, each of the semiconductor chips 103, 105, 107 and 109 actually has several hundreds to several thousands of through-chip vias therein. Since the through-chip vias vertically pass through the semiconductor chips, the more the numbers of the through-chip vias increase, the more the areas occupied by the through-chip vias increase. Thus, the areas of the semiconductor chips increase as well. In order to reduce the areas, the numbers of the through-chip vias should be decreased, so that limitations exist in improving bandwidth.

As mentioned above, the various signals and power are interfaced between the stacked semiconductor chips. In particular, in the case where multi-bits data is interfaced, operation performance may be adversely influenced by a skew that inevitably occurs due to a characteristic of interfacing.

SUMMARY

Exemplary embodiments of the present invention are directed to a semiconductor integrated circuit that may minimize area and improve I/O bandwidth.

Other embodiments of the present invention are directed to a semiconductor integrated circuit that may improve interface performance between semiconductor chips.

In accordance with an embodiment of the present invention, a semiconductor integrated circuit including first semiconductor chip and second semiconductor chip that are vertically stacked, wherein the first semiconductor chip includes a first column data driving circuit configured to transmit internal data to the second semiconductor chip in a DDR (double data rate) scheme based on an internal strobe signal, and a first column strobe signal driving circuit configured to generate first column strobe signals that are source-synchronized with first column data transmitted to the second semiconductor chip by the first column data driving circuit, based on the internal strobe signal, and transmit the first column strobe signals to the second semiconductor chip.

In accordance with another embodiment of the present invention, a semiconductor integrated circuit includes at least one master chip and at least one slave chip that are stacked, wherein the master chip is configured to transmit write data inputted from an outside, to the slave chip in a DDR scheme based on a first internal strobe signal, transmit write strobe signals that are source-synchronized with the write data transmitted in the DDR scheme, to the slave chip based on the first internal strobe signal, and receive and output to the outside read data transmitted from the slave chip, based on read strobe signals which are source-synchronized with the read data and are provided from the slave chip, and the slave chip being configured to transmit the read data provided from an inside thereof, to the master chip in the DDR scheme based on a second internal strobe signal, transmit the read strobe signals to the master chip based on the second internal strobe signal,

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and store therein the write data transmitted from the master chip, based on the write strobe signals.

In accordance with yet another embodiment of the present invention, a semiconductor integrated circuit includes first and second semiconductor chips that are vertically stacked, wherein the first semiconductor chip includes a plurality of column data driving circuit configured to receive a plurality of first column data transmitted in a DDR scheme from the second semiconductor chip, based on an alignment strobe signal, and load the plurality of first column data on a plurality of data input/output lines, and an alignment strobe signal driving circuit configured to delay a column strobe signal transmitted from the second semiconductor chip that is source-synchronized with the first column data, by a given delay time, and generate the alignment strobe signal.

In accordance with still another embodiment of the present invention, a semiconductor integrated circuit includes at least one master chip and at least one slave chip which are stacked, wherein the master chip is configured to transmit write data inputted from an outside and differential write strobe signals source-synchronized with the write data, to the slave chip based on a first internal strobe signal, and receive and output to the outside read data transmitted from the slave chip, based on first differential alignment strobe signals which are provided from the slave chip and are generated by delaying differential read strobe signals source-synchronized with the read data, by a given delay time, and the slave chip is configured to transmit the read data provided from an inside thereof and the differential read strobe signals, to the master chip in based on a second internal strobe signal, and store therein the write data transmitted from the master chip, based on second differential alignment strobe signals which are generated by delaying the differential write strobe signals by the given delay time.

In the above embodiments, since a DDR (double data rate) scheme is used when data is interfaced between the stacked semiconductor chips, bandwidth may be improved. Also, as the bandwidth is improved, the number of through-chip vias may be decreased and space may be saved.

Furthermore, since a strobe signal source-synchronized with data is also transmitted when the data is interfaced between the stacked semiconductor chips, the reliability of the data may be enhanced. In particular, when receiving the strobe signal source-synchronized with the data, because a delay operation for internally securing the setup/hold time of the data is performed, the reliability of the data may be ensured. As a consequence, operation performance may be improved when the data is interfaced between the stacked semiconductor chips.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view for illustrating a conventional semiconductor integrated circuit with a stack package structure.

FIG. 2 is a block diagram illustrating a master chip included in a semiconductor integrated circuit in accordance with an embodiment of the present invention.

FIG. 3 is a detailed diagram illustrating the data path of the master chip shown in FIG. 2.

FIG. 4 is a block configuration diagram for illustrating an interface relationship between a slave chip and the master chip included in the semiconductor integrated circuit in accordance with the embodiment of the present invention.

FIG. 5 is a block configuration diagram illustrating delay units and repeaters of the slave chip shown in FIG. 4.

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FIG. 6 is a timing diagram for illustrating a write operation among operations of the semiconductor integrated circuit in accordance with the embodiment of the present invention.

FIG. 7 is a timing diagram for illustrating a procedure in which the setup time of data is secured in the write operation explained in FIG. 6.

FIG. 8 is a timing diagram for illustrating a read operation among the operations of the semiconductor integrated circuit in accordance with the embodiment of the present invention.

DETAILED DESCRIPTION

Exemplary embodiments of the present invention will be described below in more detail with reference to the accompanying drawings. The present invention may however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the present invention to those skilled in the art. Throughout the disclosure, like reference numerals refer to like parts throughout the various figures and embodiments of the present invention.

A semiconductor integrated circuit in accordance with an embodiment of the present invention has a stack package structure, and separate descriptions thereof will be omitted herein for the sake of convenience in explanation (see FIG. 1).

FIG. 2 is a block configuration diagram illustrating a master chip included in a semiconductor integrated circuit in accordance with an embodiment of the present invention.

Referring to FIG. 2, a master chip 200 includes an input/output circuit 210 configured to transmit and receive column data to and from data pads DQ, a serial/parallel conversion circuit 220 configured to transmit and receive column data to and from the input/output circuit 210, an alignment circuit 230 configured to transmit and receive column data to and from the serial/parallel conversion circuit 220, a first column data driving circuit 240 configured to transmit and receive column data between the alignment circuit 230 and through-chip vias (TSVs) of a slave chip, a first column strobe signal driving circuit 250 configured to transmit and receive a column strobe signal source-synchronized with the column data transmitted between the first column data driving circuit 240 and the TSVs of the slave chip, to and from the corresponding TSV of the slave chip, and a control circuit 260 configured to generate control signals for controlling the input/output circuit 210, the serial/parallel conversion circuit 220, the alignment circuit 230, the first column data driving circuit 240 and the first column strobe signal driving circuit 250, in response to external commands inputted through command pads PD.

FIG. 3 is a detailed diagram illustrating the input/output circuit 210, the serial/parallel conversion circuit 220, the alignment circuit 230 and the first column data driving circuit 240, of the master chip 200 shown in FIG. 2.

In the embodiment of the present invention, for the sake of convenience in explanation, only the data path corresponding to one data pad DQ will be described.

Referring to FIG. 3, the input/output circuit 210 includes an input buffer unit 211 configured to buffer write data applied from the external controller through the data pad DQ, and an output buffer unit 213 configured to output read data DO serially transmitted from the serial/parallel conversion circuit 220, to the data pad DQ.

The serial/parallel conversion circuit 220 includes a parallel conversion unit 221 configured to output write data DIN in parallel, which is buffered through the input buffer unit 211, to the alignment circuit 230 in response to data strobe signals

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DQSRP and DQSFP and a serial conversion unit **223** configured to serially output read data RDO and FDO simultaneously transmitted from the alignment circuit **230**, to the output buffer unit **213** in response to clock signals RCLKDO and FCLKDO.

The alignment circuit **230** includes a write register unit **231** configured to simultaneously output write data RAIN and FDIN parallel transmitted from the parallel conversion unit **221**, to a pair of middle input/output lines MIO_EVEN and MIO_ODD in response to an input/output select signal SELR, and a read register unit **233** configured to simultaneously output the read data transmitted through the pair of middle input/output lines MIO_EVEN and MIO_ODD, to the serial conversion unit **223** in response to the input/output select signal SELR.

The first column data driving circuit **240** includes a first write data driving circuit **241** configured to transmit the write data transmitted through the pair of middle input/output lines MIO_EVEN and MIO_ODD, to a first through-chip via TSV01 of the slave chip in a DDR (double data rate) scheme in response to first internal strobe signals DINSTRBP_R and DINSTRBP_F, and a first read data driving circuit **243** configured to transmit the read data transmitted from the first through-chip via TSV01 of the slave chip in the DDR scheme, to the pair of middle input/output lines MIO_EVEN and MIO_ODD in response to first differential alignment strobe signals RDSTRBP_QSR and RDSTRBP_QSF.

FIG. 4 is a block configuration diagram for illustrating an interface relationship between the slave chip **300** and the master chip **200** included in the semiconductor integrated circuit in accordance with the embodiment of the present invention.

Referring to FIG. 4, the master chip **200** includes the first column data driving circuit **240** that includes the first write data driving circuit **241** and the first read data driving circuit **243** described above, and the first column strobe signal driving circuit **250** that includes differential write strobe signal driving circuits **251** and **253** and first differential alignment strobe signal driving circuits **255** and **257**. The slave chip **300** includes a second column data driving circuit **310** having a configuration corresponding to the first column data driving circuit **240**, and a second column strobe signal driving circuit **320** having a configuration corresponding to the first column strobe signal driving circuit **250**. The first and second column data driving circuits **240** and **310** are electrically connected by the medium of the first through-chip via TSV01, the rising write strobe signal driving circuit **251** and the first rising alignment strobe signal driving circuit **255** are electrically connected with a rising read strobe signal driving circuit **321** and a second rising alignment strobe signal driving circuit **325** by the medium of a second through-chip via TSV02, and the falling write strobe signal driving circuit **253** and the first falling alignment strobe signal driving circuit **257** are electrically connected with a falling read strobe signal driving circuit **323** and a second falling alignment strobe signal driving circuit **327** by the medium of a third through-chip via TSV03. Meanwhile, the first to third through-chip vias TSV01 to TSV03 are formed to vertically pass through the master chip **200** or the slave chip **300** based on the stack positions of the master chip **200** and the slave chip **300**. For example, in the case where the semiconductor integrated circuit has a structure in which the slave chip **300** is stacked on the master chip **200**, the first to third through-chip vias TSV01, TSV02 and TSV03 are formed to pass through the slave chip **300**.

First, the respective components of the master chip **200** will be described in detail.

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The first write data driving circuit **241** includes a first write data driving unit **2411** configured to output the write data transmitted through one middle input/output line MIO_EVEN of the pair of middle input/output lines MIO_EVEN and MIO_ODD to a first connection node CN01 in response to the first internal rising strobe signal DINSTRBP_R, a second write data driving unit **241_3** configured to output the write data transmitted through the other middle input/output line MIO_ODD of the pair of middle input/output lines MIO_EVEN and MIO_ODD, to the first connection node CN01 in response to the first internal falling strobe signal DINSTRBP_F and a third write data driving unit **241_5** configured to transmit the write data outputted through the first connection node CN01, to the first through-chip via TSV01 in response to a write enable signal TSV_WE.

The first read data driving circuit **243** includes a first read data latch unit **243_1** configured to latch read data TDQ_RD transmitted from the first through-chip via TSV01 in the DDR scheme, in response to the first rising alignment strobe signal RDSTRBP_QSR, a first read data storage unit **243_3** configured to store the read data latched by the first read data latch unit **243_1**, in response to the first rising alignment strobe signal RDSTRBP_QSR and output the stored read data in response to an internal read strobe signal POUTSTRBP, a first read data driving unit **243_5** configured to output the read data stored in the first read data storage unit **243_3**, to the corresponding middle input/output line MIO_EVEN in response to an inverted write enable signal /TSV_WE, a second read data latch unit **243_7** configured to latch the read data TDQ_RD transmitted from the first through-chip via TSV01, in response to the first falling alignment strobe signal RDSTRBP_QSF, a second read data storage unit **243_9** configured to store the read data latched by the second read data latch unit **243_7**, in response to the first falling alignment strobe signal RDSTRBP_QSF and output the stored read data in response to the internal read strobe signal POUTSTRBP, and a second read data driving unit **243_11** configured to output the read data stored in the second read data storage unit **243_9**, to the corresponding middle input/output line MIO_ODD in response to the inverted write enable signal /TSV_WE. Here, the first and second read data latch unit **243_1** and **243_7** may be realized by a flip-flop circuit, and the first and second read data storage unit **243_3** and **243_9** may be realized by a first-in-first-out (FIFO) circuit.

The rising write strobe signal driving circuit **251** includes a first rising write strobe signal driving unit **251_1** configured to output a high voltage VDD to a second connection node CN02 in response to the first internal rising strobe signal DINSTRBP_R, a second rising in write strobe signal driving unit **251_3** configured to output a low voltage VSS to the second connection node CN02 in response to the first internal falling strobe signal DINSTRBP_F and a third rising write strobe signal driving unit **251_5** configured to transmit the rising write strobe signal outputted through the second connection node CN02, to the second through-chip via TSV02 in response to the write enable signal TSV_WE.

The falling write strobe signal driving circuit **253** includes a first falling write strobe signal driving unit **253_1** configured to output the low voltage VSS to a third connection node CN03 in response to the first internal rising strobe signal DINSTRBP_R, a second falling write strobe signal driving unit **253_3** configured to output the high voltage VDD to the third connection node CN03 in response to the first internal falling strobe signal DINSTRBP_F, and a third falling write strobe signal driving unit **253_5** configured to transmit the falling write strobe signal outputted through the third connection node CN03, to the third through-chip via TSV03 in response to the write enable signal TSV_WE.

tion node CN03, to the third through-chip via TSV03 in response to the write enable signal TSV_WE.

The first sing alignment strobe signal driving circuit 255 includes a first input unit 255_1 configured to receive a rising read strobe signal TDQSR_RD transmitted through the second through-chip via TSV02, in response to the inverted write enable signal /TSV_WE, a first delay unit 255_3 configured to delay the rising read strobe signal outputted from the first input unit 255_1, by a given delay time and output a resulting signal, and a first repeater 255_5 configured to output the output signal of the first delay unit 255_3 as the first rising alignment strobe signal RDSTRBP_QSR with a given driving force.

The first falling alignment strobe signal driving circuit 257 includes a second input unit 257_1 configured to receive a falling read strobe signal TDQSF_RD transmitted through the third through-chip via TSV03 in response to the inverted write enable signal /TSV_WE, a second delay unit 257_3 configured to delay the falling read strobe signal outputted from the second input unit 257_1 by the given delay time and output a resulting signal, and a second repeater 257_5 configured to output the output signal of the second delay unit 257_3 as the first falling alignment strobe signal RDSTRBP_QSF with the given driving force. Here, the first and second input unit 255_1 and 257_1 may be realized by an AND logic, and the first and second delay unit 255_3 and 257_3 may be realized by a variable delay line (VDL).

Next, the respective components of the slave chip 300 will be described in detail. As described above, the slave chip 300 is configured in correspondence to the first write data driving circuit 241, the first read data driving circuit 243, the rising write strobe signal driving circuit 251, the falling write strobe signal driving circuit 253, the first rising alignment strobe signal driving circuit 255, and the first falling alignment strobe signal driving circuit 257 of the master chip 200.

A second read data driving circuit 311 includes a first read data driving unit 311_1 configured to output the read data transmitted through one global input/output line GIO_EVEN of a pair of global input/output lines GIO_EVEN and GIO_ODD, to a fourth connection node CN04 in response to a second internal rising strobe signal RDSTRBP_R, a second read data driving unit 31_3 configured to output the read data transmitted through the other global input/output line GIO_ODD of the pair of global input/output lines GIO_EVEN and GIO_ODD, to the fourth connection node CN04 in response to a second internal falling strobe signal RDSTRBP_F, and a third read data driving unit 311_5 configured to transmit the read data outputted through the fourth connection node CN04, to the first through-chip via TSV01 in response to a read enable signal TSV_OE.

A second write data driving circuit 313 includes a first write data latch unit 313_1 configured to latch write data TDQ_WT transmitted from the first through-chip via TSV01, in response to a second rising alignment strobe signal DINSTRBP_QSR of second differential alignment strobe signals DINSTRBP_QSR and DINSTRBP_QSF, a first write data storage unit 313_3 configured to store the write data latched by the first write data latch unit 313_1, in response to the second rising alignment strobe signal DINSTRBP_QSR and output the stored write data in response to an internal write strobe signal WTSTRBP, a fourth write data driving unit 313_5 configured to output the write data stored in the first write data storage unit 313_3 to the corresponding global input/output line GIO_EVEN in response to an inverted read enable signal /TSV_OE, a second write data latch unit 313_7 configured to latch the write data TDQ_WT transmitted from the first through-chip via TSV01, in response to the second

falling alignment strobe signal DINSTRBP_QSF of the second differential alignment strobe signals DINSTRBP_QSR and DINSTRBP_QSF, a second write data storage unit 313_9 configured to store the write data latched by the second write data latch unit 313_7 in response to the second falling alignment strobe signal DINSTRBP_QSF and output the stored write data in response to the internal write strobe signal WTSTRBP, and a fifth write data driving unit 313_11 configured to output the write data stored in the second write data storage unit 313_9, to the corresponding global input/output line GIO_ODD in response to the inverted read enable signal /TSV_OE. Here, the first and second write data latch unit 313_1 and 313_7 may be realized by the flip-flop circuit, and the first and second write data storage unit 313_3 and 313_9 may be realized by the first-in-first-out (FIFO) circuit.

The rising read strobe signal driving circuit 321 includes a first rising read strobe signal driving unit 321_1 configured to output the high voltage VDD to a fifth connection node CN05 in response to the second internal rising strobe signal RDSTRBP_R, a second rising read strobe signal driving unit 321_3 configured to output the low voltage VSS to the fifth connection node CN05 in response to the second internal falling strobe signal RDSTRBP_F, and a third rising read strobe signal driving unit 321_5 configured to transmit the rising read strobe signal outputted through the fifth connection node CN05, to the second through-chip via TSV02 in response to the read enable signal TSV_OE.

The falling read strobe signal driving circuit 323 includes a first falling read strobe signal driving unit 323_1 configured to output the low voltage VSS to a sixth connection node CN06 in response to the second internal rising strobe signal RDSTRBP_R, a second falling read strobe signal driving unit 323_3 configured to output the high voltage VDD to the sixth connection node CN06 in response to the second internal falling strobe signal RDSTRBP_F, and a third falling read strobe signal driving unit 323_5 configured to transmit the falling read strobe signal outputted through the sixth connection node CN06, to the third through-chip via TSV03 in response to the read enable signal TSV_OE.

The second rising alignment strobe signal driving circuit 325 includes a third input unit 325_1 configured to receive a rising write strobe signal TDQSR_WT transmitted through the second through-chip via TSV02, in response to the inverted read enable signal /TSV_OE, a third delay unit 325_3 configured to delay the rising write strobe signal outputted from the third input unit 325_1, by the given delay time and output a resulting signal, and a third repeater 325_5 configured to output the output signal of the third delay unit 325_3 as the second rising alignment strobe signal DINSTRBP_QSR with the given driving force.

The second falling alignment strobe signal driving circuit 327 includes a fourth input unit 327_1 configured to receive a falling write strobe signal TDQSF_WT transmitted through the third through-chip via TSV03, in response to the inverted read enable signal /TSV_OE, a fourth delay unit 327_3 configured to delay the falling write strobe signal outputted from the third input unit 327_1, by the given delay time and output a resulting signal, and a fourth repeater 327_5 configured to output the output signal of the fourth delay unit 327_3 as the second falling alignment strobe signal DINSTRBP_QSF with the given driving force. Here, the third and fourth input unit 325_1 and 327_1 may be realized by the AND logic, and the third and fourth delay unit 325_3 and 327_3 may be realized by the variable delay line (VDL).

FIG. 5 is a detailed diagram illustrating the first to fourth delay units **255_3**, **257_3**, **325_3** and **327_3** and the first to fourth repeaters **255_5**, **257_5**, **325_5** and **327_5** shown in FIG. 4.

In the embodiment of the present invention, for the sake of convenience in explanation, the third delay unit **325_3** and the third repeater **325_5** included in the slave chip **300** will be representatively described.

Referring to FIG. 5, the third delay unit **325_3** delays the rising write strobe signal TDQSR_WT inputted through the third input unit **325_1** by the given delay time, and outputs the resulting signal to the third repeater **325_5**. For example, the third delay unit **325_3** may be realized by the variable delay line (VDL) of which delay time is controlled in response to delay control signals $S<0:n-1>$. The delay time corresponds to a setup time for securing a setup/hold time margin when the first write data latch unit **313_1** or the first write data storage unit **313_3** latches or stores the write data TDQ_WT. For example, the delay time may correspond to $\frac{1}{4}$ cycle of the rising write strobe signal TDQSR_WT.

The third repeater **325_5** to output a delayed rising write strobe signal TDQSR_DLY delayed through the third delay unit **325_3** with the given driving force, is means for compensating the driving force of the delayed rising write strobe signal TDQSR_DLY in the case where the delayed rising write strobe signal TDQSR_DLY should be routed in parallel. Although only one second write data driving circuit **313** corresponding to one first through-chip via TSV01 is shown in FIG. 4 for the sake of convenience in explanation, it is necessary to transmit the delayed rising write strobe signal TDQSR_DLY delayed through the third delay unit **325_3** with a large driving force, when a plurality of second write data driving circuits **313** are provided in correspondence to a plurality of through-chip vias as shown in FIG. 5.

Hereafter, operations of the semiconductor integrated circuit in accordance with the embodiment of the present invention, configured as mentioned above, will be described with reference to FIGS. 6 to 8.

In the embodiment of the present invention, for the sake of convenience in explanation, a procedure in which data is inputted and outputted through one data pad will be described.

FIG. 6 is a timing diagram for illustrating a write operation among operations of the semiconductor integrated circuit in accordance with the embodiment of the present invention. FIG. 7 is a timing diagram for illustrating a procedure in which the setup/hold time margin of data is secured in the write operation explained in FIG. 6. FIG. 8 is a timing diagram for illustrating a read operation among the operations of the semiconductor integrated circuit in accordance with the embodiment of the present invention.

First, the write operation of the semiconductor integrated circuit in accordance with the embodiment of the present invention will be described.

Referring to FIG. 6, when a write command WT and write data are applied to the master chip **200** from the external controller, the write enable signal TSV_WE is activated to a logic high level after a write latency WL from the application time of the write command WT, and the write data RDIN and FDIN are outputted in parallel through the parallel conversion unit **221** from a time after the write latency WL. The write data RDIN and FDIN are loaded on the pair of middle input/output lines MIO_EVEN and MIO_ODD after $\frac{1}{2}$ cycle (0.5 tck) of an external clock CLK.

The first write data driving circuit **241** transmits the write data transmitted in parallel through the pair of middle input/output lines MIO_EVEN and MIO_ODD, to the first

through-chip via TSV01 in the DDR scheme in response to the first internal strobe signals DINSTRBP_R and DINSTRBP_F.

The differential write strobe signal driving circuits **251** and **253** generate the differential write strobe signals TDQSR_WT and TDQSF_WT source-synchronized with the write data TDQ_WT, in response to the first internal strobe signals DINSTRBP_R and DINSTRBP_F and transmit them to the second and third through-chip vias TSV02 and TSV03.

In succession, as the write data TDQ_WT is transmitted to the slave chip **300** through the first through-chip via TSV01 and, together with this, the differential write strobe signals TDQSR_WT and TDQSF_WT are transmitted to the slave chip **300** through the second and third through-chip vias TSV02 and TSV03. The second differential alignment strobe signal driving circuits **325** and **327** delay the differential write strobe signals TDQSR_WT and TDQSF_WT by the given delay time and generate the second differential alignment strobe signals DINSTRBP_QSR and DINISTRBP_QSF driven with the given driving force. The second write data driving circuit **313** latches and stores the write data TDQ_WT in parallel in response to the second differential alignment strobe signals DINSTRBP_QSR and DINISTRBP_QSF and outputs the stored data simultaneously to the pair of global input/output lines GIO_EVEN and GIO_ODD in response to the internal write strobe signal WTSTRBP.

The reason why the differential write strobe signals TDQSR_WT and TDQSF_WT are delayed by the given delay time is to sufficiently secure the setup/hold time margin of the write data TDQ_WT, which will be described below with reference to FIG. 7. Referring to FIG. 7, the differential write strobe signals TDQSR_WT and TDQSF_WT are delayed by a given delay time tDLY through the third and fourth delay units **325_3** and **327_3**. The given delay time tDLY corresponds to $\frac{1}{4}$ cycle of the differential write strobe signals TDQSR_WT and TDQSF_WT and corresponds to a setup time (tSETUP) of the write data TDQ_WT (tDLY=tSETUP). In this way, as the setup/hold time margin of the write data TDQ_WT is sufficiently secured, the write data TDQ_WT may be precisely latched at the rising edges of the differential write strobe signals TDQSR_WT and TDQSF_WT. For reference, the reference symbol DINR_SDQ designates the output signal of the first write data latch unit **313_1**, and the reference symbol DINF_SDQ designates the output signal of the second write data latch unit **313_7**.

While not shown in detail, in the case where the plurality of second write data driving circuits **313** are provided in correspondence to the plurality of first through-chip vias TSV01 (see FIG. 5), delayed differential write strobe signals TDQSR_DLY and TDQSF_DLY are generated as the second differential alignment strobe signals DINSTRBP_QSR and DINSTRBP_QSF with the large driving force through the third and fourth repeaters **325_5** and **327_5**, and the second differential alignment strobe signals DINSTRBP_QSR and DINSTRBP_QSF are routed in parallel to the plurality of second write data driving circuits **313**.

Next, the read operation of the semiconductor integrated circuit in accordance with the embodiment of the present invention will be described.

Referring to FIG. 8, when a read command RD is applied to the master chip **200** from the external controller, the slave chip **300** provides corresponding read data under the control of the master chip **200**. Operations of the slave chip **300** will be described below in detail. As the read data are loaded on the pair of global input/output lines GIO_EVEN and GIO_ODD, the second read data driving circuit **311** transmits the read data transmitted in parallel through the pair of global

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input/output lines GIO_EVEN and GIO_ODD, to the first through-chip via TSV01 in the DDR scheme in response to the second internal strobe signals RDSTRBP_R and RDSTRBP_F.

The differential read strobe signal driving circuits **321** and **323** generate the differential read strobe signals TDQSR_RD and TDQSF_RD source-synchronized with the read data TDQ_RD, in response to the second internal strobe signals RDSTRBP_R and RDSTRBP_F and transmit them to the second and third through-chip vias TSV02 and TSV03.

In succession, as the read data TDQ_RD is transmitted to the master chip **200** through the first through-chip via TSV01 and, together with this, the differential read strobe signals TDQSR_RD and TDQSF_RD are transmitted to the master chip **200** through the second and third through-chip vias TSV02 and TSV03. The first differential alignment strobe signal driving circuits **255** and **257** delay the differential read strobe signals TDQSR_RD and TDQSF_RD by the given delay time and generate the first differential alignment strobe signals RDSTRBP_QSR and RDSTRBP_QSF. The first read data driving circuit **243** latches and stores the read data TDQ_RD in parallel in response to the first differential alignment strobe signals RDSTRBP_QSR and RDSTRBP_QSF and outputs the stored data to the pair of middle input/output lines MIO_EVEN and MIO_ODD in response to the internal read strobe signal POUTSTRBP.

The reason why the differential read strobe signals TDQSR_RD and TDQSF_RD are delayed by the given delay time is to sufficiently secure the setup/hold time margin of the read data TDQ_RD. Since this was described above (see FIG. 7), detailed description thereof will be omitted herein.

While not shown in detail, in the case where the plurality of first read data driving circuits **243** are provided in correspondence to the plurality of first through-chip vias TSV01 (see FIG. 5) delayed differential read strobe signals TDQSR_DLY and TDQSF_DLY are generated as the first differential alignment strobe signals RDSTRBP_QSR and RDSTRBP_QSF with the large driving force through the first and second repeaters **255_5** and **257_5**, and the first differential alignment strobe signals RDSTRBP_QSR and RDSTRBP_QSF are routed in parallel to the plurality of first read data driving circuits **243**.

As is apparent from the above descriptions, according to the embodiment of the present invention, advantages are provided in that, since a DDR (double data rate) scheme is used when data is interfaced between semiconductor chips, bandwidth may be improved. Also, as the bandwidth is improved the number of through-chip vias may decrease and space needed may decrease. Furthermore, since a strobe signal source-synchronized with data is also transmitted when the data is interfaced between semiconductor chips, the reliability of the data may be enhanced. In particular, when receiving the strobe signal source-synchronized with the data, because the setup/hold time of the data is sufficiently secured internally, interface performance between chips may improve.

While the present invention has been described with respect to the specific embodiments, it will be apparent to those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the invention as defined in the following claims.

What is claimed is:

1. A semiconductor integrated circuit including first semiconductor chip and second semiconductor chip that are stacked, wherein the first semiconductor chip comprises:

a first column data driving circuit configured to transmit internal data in series to the second semiconductor chip based on an internal strobe signal; and

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a first column strobe signal driving circuit configured to generate first column strobe signals that are source-synchronized with first column data transmitted to the second semiconductor chip by the first column data driving circuit, based on the internal strobe signal, and transmit the first column strobe signals to the second semiconductor chip,

wherein the first column data is transmitted through a first through-chip via that vertically passes through the first semiconductor chip or the second semiconductor chip, wherein the first column strobe signals are differential strobe signals, and

wherein the first column strobe signals are transmitted through a second through-chip via and a third through-chip via that vertically pass through the first semiconductor chip or the second semiconductor chip.

2. The semiconductor integrated circuit of claim 1, wherein the first column data driving circuit transmits the internal data to the second semiconductor chip in a DDR (double data rate) scheme based on the internal strobe signal.

3. The semiconductor integrated circuit of claim 1, wherein the second semiconductor chip receives the first column data in synchronization with rising edges and falling edges of the first column strobe signals.

4. The semiconductor integrated circuit of claim 1, wherein the first semiconductor chip further comprises: an internal strobe signal generation unit configured to generate the internal strobe signal, and wherein the internal strobe signal comprises a write strobe signal or a read strobe signal.

5. The semiconductor integrated circuit of claim 4, wherein the internal data comprises write data or read data.

6. The semiconductor integrated circuit of claim 5, wherein the internal data comprises data synchronized with a rising edge of an internal synchronization signal and data synchronized with a falling edge of the internal synchronization signal.

7. The semiconductor integrated circuit of claim 6, wherein, when the internal data is write data, the internal synchronization signal is a data strobe signal that is applied from an outside.

8. The semiconductor integrated circuit of claim 5, wherein, when the internal data is read data, the internal data is applied through a pair of global input/output lines.

9. The semiconductor integrated circuit of claim 1, wherein the first column strobe signal driving circuit comprises:

a first rising column strobe signal driving circuit configured to receive a high voltage and a low voltage, and output a first rising column strobe signal of the first column strobe signals to the second through-chip via in response to the internal strobe signal and a column enable signal; and

a first falling column strobe signal driving circuit configured to receive the high voltage and the low voltage, and output a first falling column strobe signal of the first column strobe signals to the third through-chip via in response to the internal strobe signal and the column enable signal.

10. The semiconductor integrated circuit of claim 9, wherein the first semiconductor chip further comprises:

a second column data driving circuit configured to receive second column data transmitted in a double data rate (DDR) scheme from the second semiconductor chip based on an alignment strobe signal; and

an alignment strobe signal driving circuit configured to generate the alignment strobe signal corresponding to second column strobe signals that are transmitted from

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the second semiconductor chip and are source-synchronized with the second column data.

11. The semiconductor integrated circuit of claim **10**, wherein the second column data is transmitted through the first through-chip via.

12. The semiconductor integrated circuit of claim **11**, wherein the second column strobe signals are differential strobe signals, and wherein the second column strobe signals are transmitted through the second through-chip via and the third through-chip via.

13. The semiconductor integrated circuit of claim **12**, wherein the alignment strobe signal driving circuit comprises:

a second rising alignment strobe signal driving circuit configured to output a second rising alignment strobe signal corresponding to a second rising column strobe signal of

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the second column strobe signals which are transmitted through the second through-chip via, in response to an inverted column enable signal that is an inverted signal of the column enable signal; and

a second falling alignment strobe signal driving circuit configured to output a second falling alignment strobe signal corresponding to a second falling column strobe signal of the second column strobe signals that are transmitted through the third through-chip via, in response to the inverted column enable signal.

14. The semiconductor integrated circuit of claim **12**, wherein the first semiconductor chip receives the second column data transmitted from the second semiconductor chip, in synchronization with rising edges and falling edges of the second column strobe signals transmitted from the second semiconductor chip.

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